Two planes on merging routes are:
-- traveling at the same speed.
An alternate route is not available.

LineUp With Math™

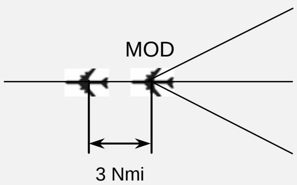
Math-Based Decisions in Air Traffic Control for Grades 5 - 9

Problem Set E

Resolving 2-Plane Traffic Conflicts by Changing Speed

Teacher Guide with Answer Sheets

Overview of Problem Set E



Goal

Estimated class time: 1-2 hours

In this Problem Set, students will determine whether two planes traveling on different merging routes will line up with proper spacing at MOD (the last intersection before the planes leave the airspace sector). If the spacing is not adequate, students will change the speed of one plane to achieve the proper spacing at MOD.

The planes are traveling at the same altitude and the same constant (fixed) speeds.

In *LineUp With Math*™, this is the first set of problems where students use speed change to achieve safe and proper spacing.

This Problem Set also introduces an optimal solution time for each Simulator problem. A “target time” is posted on the Simulator screen. This target is the minimum time required for the last plane to reach the intersection at MOD. An on-screen clock keeps track of the flight time for a student’s solution.

Each problem can be explored with the interactive Air Traffic Control (ATC) Simulator. Five of the problems can be more closely examined with Student Workbook E (print-based). The Workbook provides a structured learning environment for exploring the problems with paper-and-pencil worksheets that introduce students to pertinent air traffic control concepts as well as problem analysis and solution methods.

Objectives

Each plane is traveling at 600 knots, the maximum speed allowed. So to resolve a spacing conflict, students must reduce a plane’s speed.

Students will:

- Analyze a sector diagram to identify a spacing conflict between two planes, each traveling at the same speed.
- Resolve the spacing conflict by changing the speed of one plane.
- (Optional) Learn that a given percent reduction in plane speed yields the same percent reduction in distance traveled in the original amount of time. (For a mathematical derivation of this relationship, see Appendix III.)

Prerequisites

Before attempting the current Problem Set, it is *strongly* recommended that students complete Problem Set A that introduces essential air traffic control vocabulary, units, and representations.

It is also recommended that students complete Problem Set D that introduces students to the effects of changes in speed.

Materials

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- ATC Simulator (web-based)
- Student Workbook E (print-based)

The materials are available on the *LineUp With Math*^{TM} website:

http://www.smartskies.nasa.gov/lineup

A separate student website gives students easy access to the Simulator only (and not to the answers and solutions provided on the teacher website):

http://www.atcsim.nasa.gov

ATC Simulator

A complete description of the ATC Simulator is contained in the Educator Guide for LineUp With Math^{TM}.

For a Simulator quick start guide and an animated tutorial, visit the LineUp With Math^{TM} *website.*

Interactive Air Traffic Control Simulator

Students can explore Problem Set E with the interactive ATC Simulator. Each problem features a 2-plane conflict that can be resolved by a speed change.

The Simulator problems for Problem Set E are:

2-4*; 2-5*; 2-6*; 2-7*; 2-8*; 2-11; 2-12; 2-13; 2-14; 2-15; 2-16

Problems with an asterisk (*) are supported by worksheets in Student Workbook E.

The optimal solution time ("target time") is displayed on the screen for each Simulator problem. This time is the minimum required for the last plane to reach the intersection at MOD. An on-screen clock keeps track of the flight time for a student's solution.

For a complete set of answers and solutions to all Problem Set 5 Simulator problems, see Appendix I of this document.

For a discussion of the key points associated with the first five Simulator problems, see the worksheet notes in the following Student Workbook section.

Student Workbook

It is recommended that you have a copy of Workbook E open while you read these notes.

The worksheet title is the same as the associated Simulator problem.

The Student Workbook consists of five worksheets, one for each of the five featured Simulator problems listed below.

Simulator Problem	Worksheet Title
2-4*	Problem 2-4
2-5*	Problem 2-5
2-6*	Problem 2-6
2-7*	Problem 2-7
2-8*	Problem 2-8

Each problem features a spacing conflict with different starting conditions. As students progress through the worksheets, they likely will require less guidance and structure, and the worksheets reflect this.

In the sector diagram, each route flows only ***towards*** *MOD. E.g., a plane may fly from MINAH to OAL, but cannot fly from OAL to MINAH.*

For a complete set of answers to each worksheet, see Appendix II of this document.

For each worksheet, the key points are briefly described as follows.

Worksheet: ***Problem 2-4: Assure Spacing Between 2 Planes***

- After students identify the spacing conflict at MOD, they determine it will take each plane 3 minutes to arrive at MOD. After students decrease the speed of one plane, the faster plane will still take 3 minutes to arrive at MOD. So, the planes will fly 3 minutes before Ideal Spacing must be achieved.
- To resolve the spacing conflict, students begin by reducing the speed of one plane by 60 knots. (Either plane can be selected since neither has a headstart.) At the reduced speed, this plane will travel 1 Nmile less each minute.
- Finally, students apply the 1 Nmi/minute distance reduction for 3 minutes to achieve Ideal Spacing (3 Nmi) exactly at MOD.

Worksheet: ***Problem 2-5: Assure Spacing Between 2 Planes***

- Using the same problem-solving approach as in Problem 2-4, students determine it will take 2 minutes for each plane to arrive at MOD. After students decrease the speed of one plane, the faster plane will still take 2 minutes to arrive at MOD. A single 60-knot speed decrease will achieve only a 2 Nmi spacing in 2 minutes at MOD. This is less than Ideal Spacing at MOD.
- To resolve the spacing conflict, students must make a 120-knot speed decrease (the equivalent of **two** 60-knot decreases).
- This results in 4-Nmile spacing at MOD, which is greater than Ideal Spacing. The students are asked to suggest a way to achieve Ideal Spacing at MOD. This requires increasing the slower plane's speed to the same speed (600 knots) as the leading plane as soon as Ideal Spacing is achieved.
- In the next problem, Problem 2-6, students will be given the opportunity to make such a speed increase.

Worksheet: ***Problem 2-6: Assure Spacing Between 2 Planes***

- Students use the same problem-solving approach as in Problem 2-4. However, unlike Problems 2-4 and 2-5, one plane has a headstart (1 Nmi). For the trailing plane, a single 60-knot speed decrease will result in more than Ideal Spacing at MOD.
- The 3-Nmile Ideal Spacing is achieved before MOD. As soon as this Ideal Spacing is achieved, the trailing plane's speed should be increased to the same speed as the leading plane. This will maintain Ideal Spacing all the way to MOD and beyond.
- Students are asked to specify the number of minutes (2 minutes) after which they will speed up the trailing plane. This is the number of minutes at which Ideal Spacing will be achieved.

Worksheet: ***Problem 2-7: Assure Spacing Between 2 Planes***

In this problem, students work with decimals.

- Students use the same problem-solving approach as in Problem 2-6. However, in the current problem, both planes pass through OAL before they arrive at MOD. So students must check for Minimum Separation (2 Nmi) at OAL as well as for Ideal Spacing 3Nmi at MOD.
- First, students check for Ideal Spacing at MOD. This is because the goal is to have Ideal Spacing at MOD. After the students have determined the strategy to achieve this goal, they next check to see if their strategy violates Minimum Separation at OAL. (If it does, they must change their initial strategy to resolve the violation at OAL.)
- Since each plane is 25 Nmi from MOD, they will arrive at MOD at the same time. Since there is **no** spacing between the planes at MOD, this does not meet the Ideal Spacing goal (3 Nmi).
- To resolve the spacing conflict, students begin by reducing the speed of one plane by 60 knots. (Either plane can be selected since neither has a headstart.) At the reduced speed, this plane will travel 1 Nmile less each minute.
- The faster plane takes 2.5 minutes to travel 25 Nmiles to MOD at 600 kts. In 2.5 minutes, with a 60-knot speed reduction, the slower plane will fall behind 2.5 Nmi (2.5 minutes x 1 Nmi/minute = 2.5 Nmi). This is less than Ideal Spacing at MOD.
- To achieve at least Ideal Spacing at MOD, a 120-knot speed decrease is required. This speed decrease will yield a 5 Nmi spacing at MOD (2.5 minutes x 2 Nmi/minute = 5 Nmi).
- Before the planes reach MOD, they will each pass through OAL. So students must check for Minimum Separation at OAL. Each plane starts 15 Nmi from OAL. The faster plane takes 1.5 minutes to travel 15 Nmi to OAL. A 120-knot speed decrease (2 Nmi per minute) will result in a 3 Nmi separation at OAL (1.5 minutes x 2 Nmi/minute = 3 Nmi). This meets the Minimum Separation requirement of at least 2 Nmi. This also provides Ideal Spacing at OAL.
- To maintain the 3 Nmi Ideal Spacing all the way to MOD and beyond, students must speed up the slower plane exactly at OAL. (Note: Students made similar calculations in Problem 2-6.)

Worksheet (Optional): ***Understand the % Method***

- A plane, traveling at its original speed, can cover a certain distance in a given amount of time. If the plane's speed is reduced by a certain percent, then in the given amount of time, the distance covered is reduced by the same percent. (For a mathematical derivation of this relationship, see Appendix III.)

- This percent relationship is especially easy to apply in the *LineUp With Math*^{TM} problems since all speed reductions are done in increments of 10% of the original speed. In particular, the original plane speed is always 600 knots and the original speed is always reduced in 60-knot increments. (Note: 60 is 10% of 600.) With a 10% speed reduction, the distance traveled is also reduced by 10% (of the original distance). To find 10% of the original distance, students need only divide the distance by 10, that is, they need only move the decimal point one place to the left.

- Note that with this percent method, students do *not* need to calculate the amount of time it will take the lead plane to reach MOD (as they have done in previous worksheets).

Worksheet (Optional): ***Problem 2-8: Assure Spacing Between 2 Planes***

- In this problem, students are guided through the percent method introduced in the previous worksheet.
- The leading plane starts 20 Nmi from MOD. The trailing plane starts 21 Nmi from MOD. In the time it takes the leading plane to travel 20 Nmi to MOD, the trailing plane will also travel 20 Nmi. So to calculate the % decrease in travel distance for the trailing plane, students must use 20 Nmi (**not** 21) for the distance traveled.

Answer Sheets

For a set of answers and solutions to all Simulator problems, visit the LineUp With Math^{TM} *website.*

Answer sheets for each of the Problem Set E Simulator problems can be found in Appendix I of this document.

Answer sheets for each worksheet in Student Workbook E can be found in Appendix II of this document.

A mathematical derivation of the Percent Method can be found in Appendix III of this document.